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COMPUTATION OF HIGHWAY IMPACTS

Bibliography by Alan M. Voorhees & Associates, Inc.
Review and Conclusions by the Colombian Research Corporation,
for the Instituto Colombiano de Planeación Integral

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COMPUTATION OF HIGHWAY ECONOMIC IMPACTS

Colombian Research Corporation commissioned the basic work for this bibliography from Alan M. Voorhees & Associates, Inc. and then prepared the Review and Conclusions for their client Instituto Colombiano de Planeacion Integral.

The bibliography which is presented therewith includes the documents which we believe most representative in the field of highway planning during the last few years, especially in the U.S.A., the leading country in these studies.

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Part II: OBSERVATIONS AND RECOMMENDATIONS
(translated from the original Spanish by Louise Lodge and Nilda Soler)

On analyzing, in preliminary form, the documents mentioned in the adjoining bibliography, one observes that they represent four kinds of studies, to wit:

a. Marginal effects

b. Effects of local value

c. Economic effects on users and neighboring users (those who own property along the highway or road)

d. Global economic effects

Among the type (a) studies the outstanding ones are those marked in the bibliography with numbers: 9, 34, 56, 57, 65, 66, 68, 69, 73, 79, 81, 83, 99, 103, 105, 111, 120, 122, 135, 145, 157, 161, 165, 169, 178, 202, 218, 234, 235, 239, 241, 245.

The studies, in their turn, represent two types of principal conclusions which are: those which point out losses in the economic activities of towns which have been bypassed by a new highway, as is the case os study no. 111; and those which point out a beneficial final result for said towns especially when based on longer term studies which indicate how initial losses were compensated in the long run by activities which did not need direct access to the highway, which are the majority.

Among the type (b) studies one observes that the majority are oriented to refute the objections of the owners whose farms are crossed or are near to the projected road. (Nos. 2, 13, 19, 26, 34, 37, 39, 42, 49, 59, 60, 64, 70, 77, 85, ..0, 112, 123, 125, 128, 138, 153, 154, 171, 175, 181, 193, etc.) If indeed the majority of these studies arrive at the conclusion that the impact on neighboring property is generally positive, there remain in some cases serious doubts on those results especially when they are based solely on price date before and after construction of the highway.

As an alternative method to that empirical form of calculation, there is suggested the establishment of so-called "areas of control" which would be land zones similar, as far as possible, to those which are going to be affected by the new highway but, naturally, a good distance from it.

Although the process of selection of the "areas of control" is complex, the results which are obtained are more realistic since one succeeds in neutralizing in great part the effect of "changes of value" due to the general price increase in the corresponding region.

An interesting exception in this type of study is the case of the campaign instigated by Antioch College in which is whown that at times there are factors of a cultural, esthetic and civic type which go beyond mere economic considerations for a highway plan. (See: HUNT, Kenneth, ed. Witness to Wilderness. Ohio, 1959.)

Another aspect which offers an objection to the majority of evaluative studies is that they do not point out clearly a system to compensate for the "devaluation" suffered by affected lands precisely by the fact of an increase in the promise of such lands within the general situation of demand and prices.

The general conclusion is that the studies of "evaluation" of land affected by the highway are not sufficent but must be complemented by studies of origin-destination of traffic in order to be able to distribute rationally the costs and benefits among the users and non-users of the highway.

The third group of reports (type c) is exactly the one which has under consideration the two kinds of effects mentioned above. Among studies of this type those numbered 1, 6, 11, 20, 38, 44, 72, 90, 140, 150, 164, etc. are the most outstanding. In relation to Colombia, we still believe that the only serious work of this type accomplished up to the present is that of the Medellin-Santuario-La Dorada Road executed by INTEGRAL (calculation of users) and I. COPLAN (calculation of socio-economic impact) and which appears in the bibliography as no. 104.

Finally one can observe the recent appearance of studies on the cost-benefit impact of highway investments based on the so called Econometric Models which involve the use of computers because of the extraordinary volume of data and operations necessary.

The need of this kind of study has been pointed out by academic investigators such as Professors Mohring and Harwitz (see bibliography no. 149) who point out that the conventional types of studies on the effect of roads do not go as far as measuring the total impact in the whole regional or national economic structure.

Even the studies which measure the benefits obtained or obtainable by the firms and persons affected by a highway investment, these authors say, point out the need of advancing still more in analysis and seeking further effects of those same benefits. Thus, for example, in the case of a group of firms who benefit markedly by a new highway (like those firms which operate the well known shopping centers in the U.S.A.), those profits can be weighed against the losses of the firms which formerly obtained the volume of sales which was transferred to the new commercial center.

Besides, say these authors, within an economy with a high unemployment rate, the investment in roads can have some beneficiaries other than the users and the people who live along the highway. Such is the case of highway projects which really seek to open new labor opportunities and to use other resources which are underemployed within the global economic structure.

In a parallel manner they point out, as was to be expected, the fact that some highway investments which are judged justified by some of the conventional methods of analysis, can involve some high hidden costs when they absorb resources which are needed more urgently in other parts of the economy.

Such would be the case which is presented in our own region of Medellin, through works which are going to diminish resources which the integral development of the metropolitan region needs with greatest urgency.

From all the above, one arrives at the the appropriateness os using new methods of calculation which attempt to incorporate all the direct and indirect effects of a highway investment since its cost will have to be applied to every economic activity which may make use of the road system or may benefit from its improvement.

Hence the need of having recourse to systems on the basis of econometric models which we are going to explain briefly. (Bibliographies no. 14, 16, 22, 67, 89, 96, 106, 116, 121, 133, 148, 149, 168, 187, 192, 195, 196, 197, 210, 212, 226, 238).

REGIONAL PROGRAMMING

The methodology of the integral analysis of an economic structure has two principal bases which are the technique of Input-Output initiated by W. Leontief:

> "Quantitative Input and Output Relations in the Economic System of the United States". Review of Economic Statistics, August, 1936.

and the technique of Lineal Programming initiated by G. Dantzig:

> "Maximization of a Linear Function of Variables Subject to Linear Inequalities", in Activity Analysis of Production and Allocation. J. Wiley, 1951.

By means of an econometric model which is constructed by utilizing those resources of analysis one can estimate the global impact which any change of any one of the elements in the economic structure produces and one can localize that impact in each one of the sectors or ACTIVITIES in which one may wish to divide the economic structure.

Because we believe that it is important to make known the theoretical basis and the operational implications of this methodology, we permit ourselves to give herewith a synthesis of its mechanics, based on the work of Barbara Berman for the Metropolitan Region of New York (see bibliography no. 14).

In this method all the firms or production units of the region are classified carefully according to the final destination of their products. Those which export (outside of the region) a high percentage of their production are designated as firms of "national market" or simply National firms. Those which sell the major part of their production within the region studied are called firms of "local market" or simply Local firms.

Now then, the statistical data of production are computed in terms of industries, by which term is understood a group of firms or productive units which utilize a similar technology. With this criterion as a basis, 43 INDUSTRIES were selected for a model of the Metropolitan Region of New York, of which 10 were entirely local, 8 entirely national, and 25 were mixed.

We establish, then, the "assumption" that each INDUSTRY has two kinds of products: those of the local market and those of the national market. The local products, in their turn, are supposed to be destined for three classes of buyers: the final consumers; the firms which use them as inputs for their own production; and the government in all its forms or agencies.

In this form we have the bases for constructing the equations of the econometric model and we proceed in the following manner:

A) - Equations of local demand:

1. - Demands of firms (intermediate inputs)

The demands of these firms are, in turn, of two kinds:

a) the demands for goods and products which have a volume proportional to the volume of production of the purchasing firm, and

b) the demands for inputs which are destined to increase the capacity of production of the purchasing firm, or rather, capital goods.

The Demands of type a) are expressed by the formula:

$$(a_{ij}) \; X_j^t \qquad [1]$$

in which a_{ij} is the coefficient of volume or rather the constant which relates the volume of production of the LOCAL firms of INDUSTRY j in the year t (represented in dollars by X_j^t

with the purchases which those firms make from the firms of INDUSTRY i.

The demands of type b) are assumed to be proportionate to the increase in production which INDUSTRY j desires. This increase is represented (in dollars) by the formula

$$X_j^t - X_j^{t-10}$$

of, the volume of production in the year t minus the volume of production in the year t - 10. Periods of 10 years are chosen on the basis of the census practice of the U.S.A. For other countries this interval of years will be revised. If C ij is the coefficient of capacity which relates the increase in volume to the demands on products of INDUSTRY i, such demand for a year will be represented thus:

$$C_{ij}\left(\frac{X_j^t - X_j^{t-10}}{10}\right) \qquad [2]$$

According to this, the total of purchases (demand) of the firms in INDUSTRY j from the Local firms of INDUSTRY i will be represented by the sum of the equations [1] and [2], or:

$$a_{ij} X_j^t + \frac{C_{ij}}{10}\left(X_j^t - X_j^{t-10}\right)$$

which is equivalent to:

$$\left(a_{ij} + \frac{C_{ij}}{10}\right) X_j^t - \frac{C_{ij}}{10} X_j^{t-10} \qquad [3]$$

2.- Demand of final consumers.

In order to calculate the demand of the final consumers in the region on the products of INDUSTRY i the following formula is utilized:

$$\text{Consumer purchases, year } t = d_i P^t + f_i Y^t \qquad [4]$$

in which P^t is the regional population in the year t; Y^t is the disposable

personal income in the region, year t; and d_i, f_i are the coefficients which make the former identity valid.

3. - Demands of the government

Finally, the purchases of different agencies of the government from Local firms of INDUSTRY i are represented thus:

$$\text{Government purchases} = a^t_{ig} P^t + b^t_{ig} \qquad [5]$$

in which a^t_{ig}, b^t_{ig} are empirical coefficients which achieve the identity.

To summarize, we have established that the local demand upon Local products of INDUSTRIA i is obtained by adding expressions 3 , 4 , and 5 , or, the demands corresponding to the firms, consumers and government of the region. This is:

$$X^t_{iL} = \sum \boxed{3} + \boxed{4} + \boxed{5}$$

$$= \sum \left(a_{ij} + \frac{c_{ij}}{10} \right) X^t_j - \sum_{j=1}^{43} \frac{c_{ij}}{10} X^{t-10}_j +$$

$$+ \left(d_i P^t + f_i Y^t \right) +$$

$$+ \left(a^t_{ig} P^t + b_{ig} \right)$$

B. EQUATIONS OF NATIONAL DEMAND:

Besides, one must calculate the demand of NATIONAL products of INDUSTRY i, that is, for the 33 industries which have such a demand. (The 10 "Local" Industries do not).

That demand is represented by the following expression:

$$X^t_{iN} = \frac{e^t_{iN}}{h^t_i} \qquad [7]$$

in which e^t is the sum total of jobs existing in the NATION for INDUSTRY i, and h^t_i is a coefficient of productivity, that is, the number of jobs which is required by each million dollars of production INDUSTRY i.

Consequently, the TOTAL DEMAND (national and local) on products of INDUSTRY i will be represented by the sum of expressions [6] and [7] which produces a system of 43 equations (with 45 unknowns) of the form:

$$X^t_i = X^t_{iL} \; X^t_{iN}$$

$$= \sum_{j-1}^{43} \left(a_{ij} + \frac{c_{ij}}{10}\right) X^t_j - \sum_{j=1}^{43} \frac{c_{ij}}{10} X^{t-10}_j +$$

$$+ \left(d_i P^t + f_i Y^t\right) +$$

$$+ \left(a^t_{iq} P^t + b^t_{iq}\right) +$$

$$+ \frac{e^t_{iN}}{h^E_i}$$

(1)
(2)
⋮
(43)

In order to be able to give solubility to this system we have recourse to four new equations (with 2 new unknowns) which produces an equilibrated system of 47 equations and 47 unknowns.

These new equations are the following:

The Disposable Personal Income in the region depends not only on the regional production but on other factors such as income resulting from investments of its inhabitants in other regions; payments of the government to residents of the region; payments (negative) of regional firms to residents outside the region; utilities not distributed by (or not assessed) firms in the region; taxes, direct, indirect and transfer payments; depreciation.

This situation is simplified by means of the expression:

$$Y^t = K^t E^t \qquad (44)$$

in which K^t is the empirical constant which relates the Disposable Personal Income with the total number of jobs in the region.

We have, then, the "Malthusian" equation which relates the Population with Employment, thus:

$$P^t = m^t E^t \qquad (45)$$

An equation which relates official employment with the total Population, thus:

$$e_g^t = q^t P^t + S^t \qquad (46)$$

And finally we have an accountable identity which is the sum of employment in all the Industries of the region (one of which is official bureaucracy) thus:

$$E^t = e_1^t + e_2^t + e_3^t + \dots + e_{42}^t + e_g^t + e_h^t \qquad (47)$$

in which e_h^t are the domestic occupations in the region.

As can be seen, the system of simultaneous equations requires a series of technological coefficients (a, c, h) and a series of sociological coefficients ($b, d, f, K, m\ q, s$) the calculation of which represents a formidable statistical problem.

We are not going to write at length here upon the methods of solution of these systems of equations since, on the one hand, that is not the object of the work, and on the other, we still lack a more advanced aspect of the methodology in study, or rather, that which corresponds to the Multi-Regional Programming.

MULTI-REGIONAL PROGRAMMING

Assuming that the "net benefit" may be a just criterion for distributing proportionately the burdens of a road plan (A debatable criterion for what would one say is an investment in public education, for example, were to be charged to those who receive its benefits?), it is indispensable, then, to try to localize not only in the region physically affected by a new road, but in the whole national economic structure, the distribution of the corresponding benefits.

Here appears immediately a criticism which the transportation analyst makes to the econometric model which has been described, and it is in the words of Mohring and Harwitz that the "economist frequently finds it suitable to abstract the part of space in the economic structure". It becomes necessary, therefore, to separate from the system of equations formulated for the regional economic matrix, all the branches of the transportation industry (highway, air, railroad, water, etc.) and in place of endowing them with technological coefficients of a type similar to those used for other industries, there will have to be established series of coefficient of transport for the cost of mobilization of all the products which enter and depart from the regions being studied.

Such a model will be obviously of such a magnitude and complexity that it is doubtful that it can come to be constructed, not so much because of the possible limitation of available computation means, but principally, because of the recognized deficiency of actual statistical documentation.

This statistical limitation is not only applicable to underdeveloped countries like Colombia but is found also in the most advanced countries like the U.S.A. So it is that in a consultation with us over the matter, Professor Edgar M. Horwood of the Department of Computation, College of Engineering, University of Washington, has answered us in the following form:

"We believe, basically, that the benefits of the non-users, Producers and Consumers, resulting from the best roads, are additional benefits which we cannot easily calculate and are beyond the benefits of direct users which we can measure and which serve to orient our decisions". (Letter of June 28, 1968).

The Model which is being developed at present in experimental form to study the volume of traffic among the 3,076 counties of the S.S. is limited to the calculation of the movement of vehicles on a Simplified Network of routes.

For this model the following basic equations are used:

a) Trips from County A toward County B:

$$T_{a-b} = \frac{G_a A_b}{\sum A_a}\left(0.001 + \frac{877,491}{D_{a-b}^{2.75}}\right)$$

in which: G_a = total trips originating in County A.

A_b = factor of attraction of County B

$$\sum A_a = 0.001\left(\sum P - P_a\right) + 877,491\left(\sum \frac{P_n}{D_n^{2.75}} - \frac{P_a}{D_{a-b}^{2.75}}\right.$$

here, in turn, we have:

$\sum P$ = National population

$\sum \frac{P_n}{D_n^{2.75}}$ = the sum total of: population in each County (n), divided by the distance (at 2.75) from County A to said County n. (For all the Counties of the U.S.A.

D_{a-b} = the distance 9by air0 between the centers (of population) of Counties A and B.

b) Trips generated in County B with destination in County A:

$$T_{b-a} = \frac{G_b A_a}{\sum A_b}\left(0.001 + \frac{877,491}{D_{b-a}^{2.75}}\right.$$

c) Assuming that every trip generated in A with destination in B (and vice versa) returns to the County of origin, it will be estimated that trips which leave from A toward B will be the sum of a) and b), thus:

$$\sum T_{a \rightarrow b} = T_{a-b} + T_{b-a} = \sum T_{b \rightarrow a}$$

With a basis on these equations the general model has been operated and the corresponding results have been confronted with real appraisements of the traffic on a good number of roads and so we have been able to arrive at a very acceptable adjustment of said model.

This model does not take into account the intra-urban trips which make up approximately 70 percent of the total vehicular miles in the U.S.A.

Finally, the model assumes initially that all roads are of equal specifications and are very good, and this requires gradual corrections by means of hindrance coefficients which are applied in order to adjust the model to the real conditions of the roads.

In these conditions the predictive results of the Inter-County U.S.A. model are still very tentative and costly studies are being advanced in order to give them greater precision.

In synthesis, one can take as a conclusion from this preliminary report, that the systems of evaluation of road impacts which are limited to the benefits of users and neighbors are pointed out as insufficient for arriving at a just apportionment of costs of highway investment. On the other hand, the whole new method of study based on regional and multi-regional models tends to demonstrate that the impact of highway investments is distributed through the whole national economic structure and such investments should be financed, consequently, by means of general taxation such as the income tax and consumer's tax.

To confirm this thesis it must be noted that the government of the U.S.A. finances its grandiose National Highway System with a basis on appropriations within the general budget and with direct contributions of taxes on motor fuel, vehicles and tires.

And it is worth while to observe, also, that the Federal Government follows in that road program the recommendations of the States on the order of priority which must be given to each part of the system within the frontiers of each state.

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